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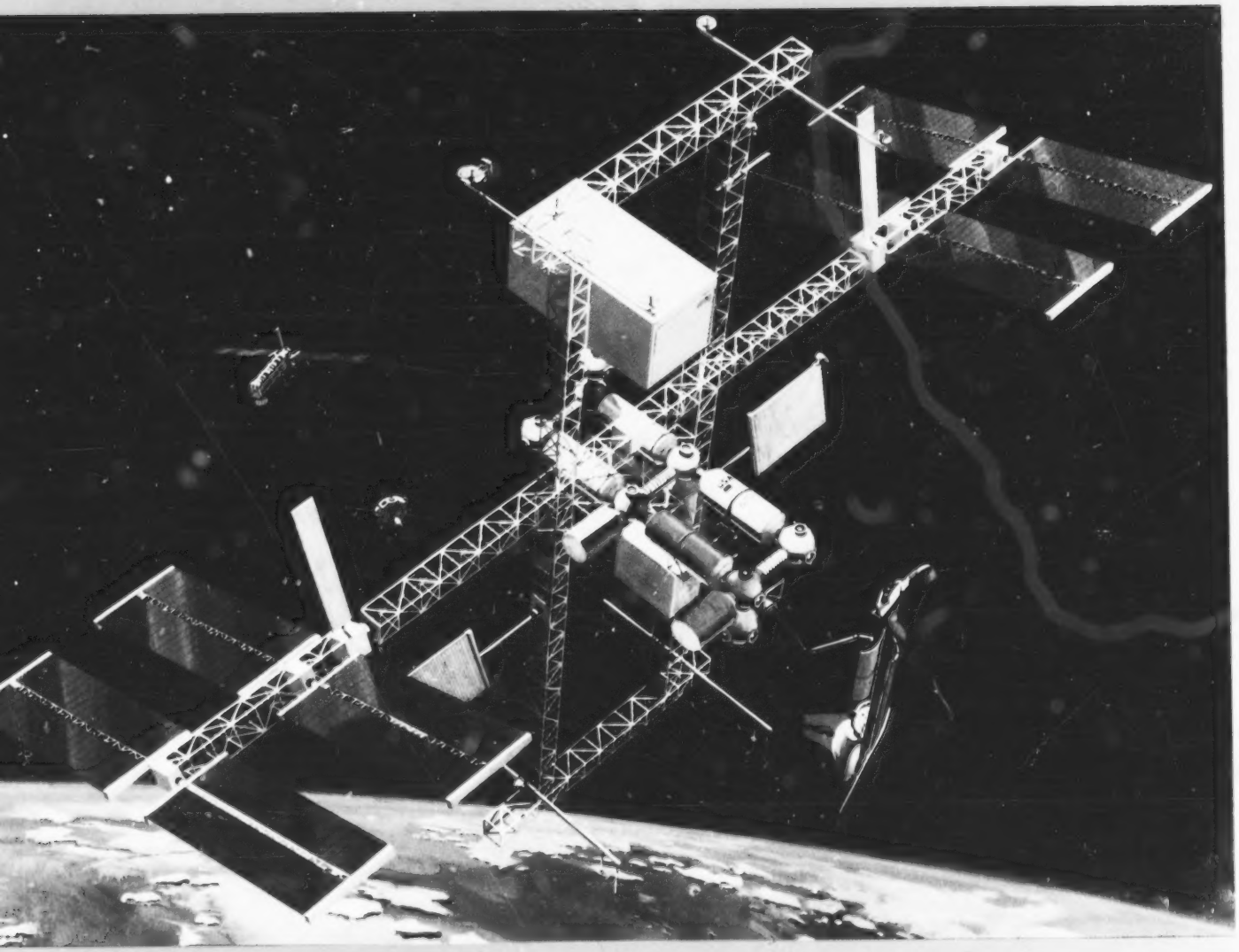
The Partnership:

Space Shuttle, Space Science and Space Station

by
Philip E. Culbertson and Robert F. Freitag



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Platforms are an integral part of the Space Station Program. Such unmanned free-flyers are expected to be co-orbiting with the Station's manned base and to fly in polar orbit as well. User requirements for the Space Station platforms are being studied extensively. These will be incorporated in the "Phase B" systems design work currently underway. Shown here is a picture of what a Space Station platform might look like.

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APR 16 1986

It has now been well over a year and a half since President Reagan directed NASA to develop within a decade a permanently manned Space Station. In this time the program has made significant progress. We have defined a Space Station functional requirements envelope as a goal for the capabilities the Station must provide for users. We have initiated a major effort in Space Station technology development. We have begun a competitive Phase B definition and preliminary design study with eight teams now under contract. We have listened to a variety of advisory panels, such as the Task Force on Scientific Uses of the Space Station chaired by Peter Banks. We have begun the development of an operations concept, and directed our attention to the analysis of operational costs. In addition, we have signed Memoranda of Understanding with Canada, the European Space Agency, and with Japan, that provide a framework for cooperation during Phase B. So the program is well underway and we anticipate continued progress in the months ahead.

The Space Station will be a versatile system serving a diverse range of functions. NASA anticipates the permanently manned Space Station to be:

- a national laboratory in space, for the conduct of science as well as the development of new technologies and related commercial products;
- a permanent observatory, to look down upon the earth and out into the universe;
- a servicing facility where payloads and spacecraft are resupplied, maintained, upgraded and, if necessary, repaired;
- a transportation node where payloads and vehicles are stationed, processed and propelled to their destinations;
- an assembly facility where, due to ample time on orbit and the presence of appropriate equipment and personnel, large structures are put together and checked out;
- a manufacturing facility where human resourcefulness and the servicing capability of the Station combine to enhance commercial opportunities in space;
- a storage depot where payloads and parts are kept on orbit for subsequent deployment; and,
- a staging base for future endeavors in space.

The Space Station will also be:

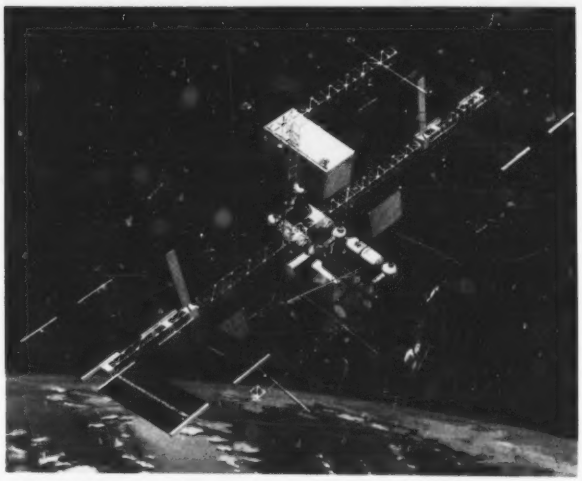
- a striking example of Free World unity and capabilities; and,
- a highly visible yet peaceful demonstration of U.S. leadership.

The Space Station will be a highly capable, multipurpose system. It will enable us to meet a wide range of NASA mission requirements, as well as the mission requirements of other Federal agencies, private organizations and foreign governments.

The Space Station itself will consist of several elements. There will be a manned base, where the crew——initially six to eight people——will live and work. There will also be a number of unmanned platforms suitable for scientific or commercial activities. One or more ot these platforms may be co-orbiting with the manned base. One or more may be in polar orbit. The platforms will be tended by an Orbital Maneuvering Vehicle (OMV), a small "tug" that can inspect and retrieve satellites and which will be enhanced in the future to provide repair capabilities. One of the OMV's is expected to be kept at the Space Station base. Another Space Station element will be the logistics system — flight modules and ground based equipment. These are essential to a facility that is expected to operate year round for some twenty to thirty years.

The Space Station is unlike any program NASA has undertaken, for it will be a permanent facility in space. No longer will we simply visit space. When the Space

"POWER TOWER" — the picture shown here is an earlier Space Station configuration termed the "power tower." It was used by NASA as a reference configuration in the early stages of the Phase B definition and preliminary design activity.



"DUAL KEEL" — this picture illustrates an artist's conception of a more recent Space Station configuration, known as the "dual keel." In comparison to the "power tower" this configuration offers a number of advantages. The laboratory and habitat modules have been moved closer to the center of gravity, more space is provided for attached payloads and greater structural stiffness is realized.

Station becomes operational we will be living and working in space around the clock, 365 days a year, well into the next century. The Space Station is also different because it is evolutionary in character. The initial baseline Space Station will have built-in the potential for phased, evolutionary development to meet future requirements.

This evolutionary character and the permanent nature of the Space Station make the undertaking truly unique. They place a new and difficult engineering challenge upon NASA and her industrial partners. But the rewards will be great, for the Space Station will significantly enhance United States capabilities to operate in space.

Space Shuttle

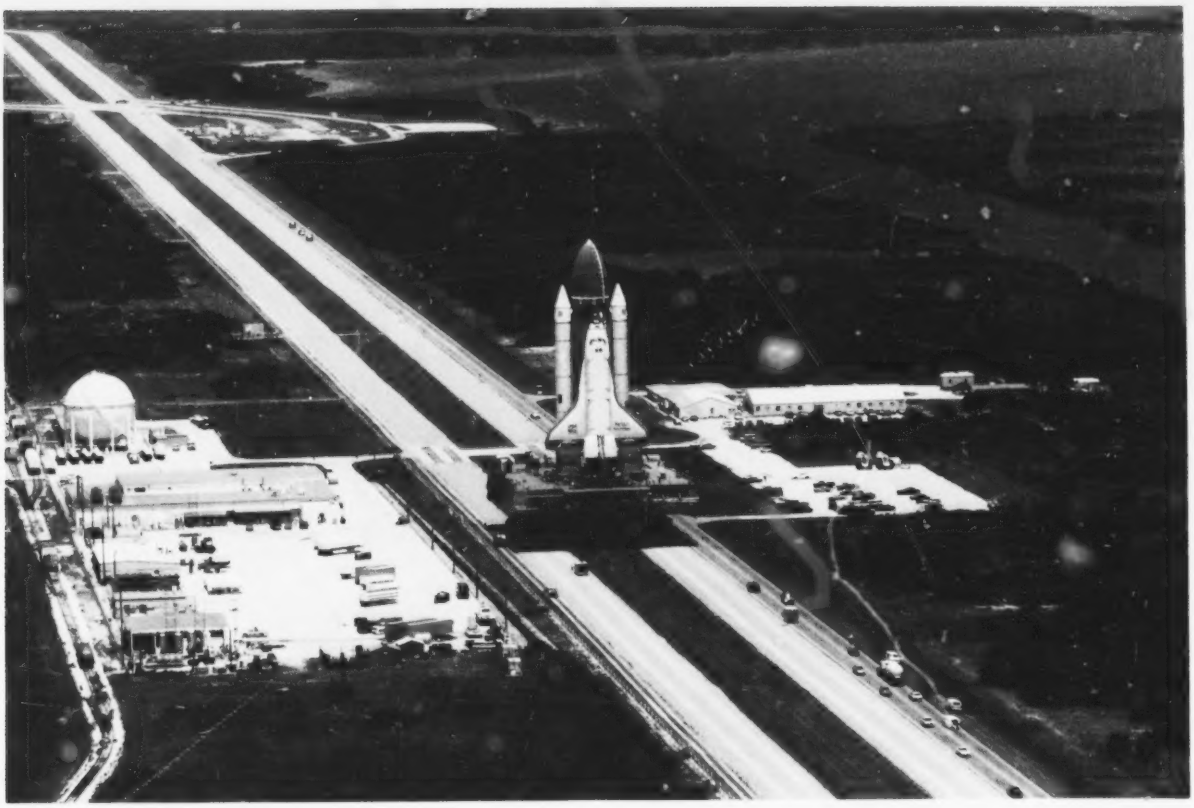
As the Space Transportation System remains the nation's primary launch system for both national security and civil government missions, the Space Shuttle will be the principal transportation system for the Space Station. With its large payload bay, its unique capability to carry men and women to and from orbit, and its frequent flight rate, the Shuttle is ideally suited to service the Space Station. Indeed, a system such as Shuttle underlies the very concept of a Space Station, a permanent facility that is predicated upon the existence of an efficient, man-rated transportation system.

The Space Station will utilize the capabilities of the Space Shuttle in several ways. Before discussing the number of Shuttle-equivalent flights likely to be required, let us review briefly the categories of flights we envision.

- **Delivery** - the Space Shuttle will carry aloft the various Space Station elements and structure. Included in this will be the components for the manned base as well as the unmanned Space Station platforms. The Shuttle will also be used for the assembly and checkout of the Space Station system.

- **Users** - the Space Station scientific, commercial, and technological user communities will employ the Space Shuttle to transport their instruments to and from the Station. Materials made in space aboard the Station will be returned to earth aboard the Shuttle. The Shuttle will also transport the scientists and engineers from the user communities who will work with their equipment aboard the Station as crew members.

- **Logistics** - supplies for the crew and the Station will be brought up by the Space Shuttle. Food, fuel, and various items of equipment will be required in substantial quantity. We anticipate periodic logistics flights to the Space Station in order to maintain its ongoing operations. We also anticipate the availability of an orbiter to respond



to a Space Station emergency. This can be accomplished, we believe, without tying up an orbiter for this express purpose.

- **Evolutionary Station** - the Space Station will be designed to evolve in capability over time. Space Shuttle flights will be required to launch and assemble additional modules, structure, and equipment as the Station evolves.

We want to emphasize that our estimates for the number of Shuttle-equivalent flights in these categories for the Space Station are very preliminary in nature. We have only just begun our definition and preliminary design activities and our understanding of operational and user requirements is not yet mature. While the estimates provided are the best we can calculate at this time, they may change as we come to a fuller understanding of the flight categories and the Space Station itself.

Delivery of the Space Station elements, which we believe will take about twelve to eighteen months to accomplish starting in 1992, is likely to require approximately 12 Shuttle flights. This estimate includes 2 launches for international elements of the Space Station manned base and 3 launches for Space Station platforms. This estimate of 12 flights is, of course, dependent upon the Space Station configuration selected and upon the nature of the elements that may be provided by our foreign partners.

Our analysis indicates a substantial number of Space Station Shuttle flights required through 1995. Significantly, the estimate for annual launch requirements remains relatively high after the Space Station is assembled. Because several of these flights are likely to carry payloads originally planned for non-Station related operations, we continue to expect that NASA requirements for launch vehicles will be able to be met during the Space Station era.

We again wish to emphasize the preliminary nature of this estimate. While it is clear that the Space Station Program will place launch requirements upon the Space Shuttle, the exact number and timing of these requirements are far from certain at this time. The Space Station Program expects to utilize the fleet of orbiters and assumes that, at one time or the other, each of the orbiters will be employed on a Space Station mission. While we also assume that most of the

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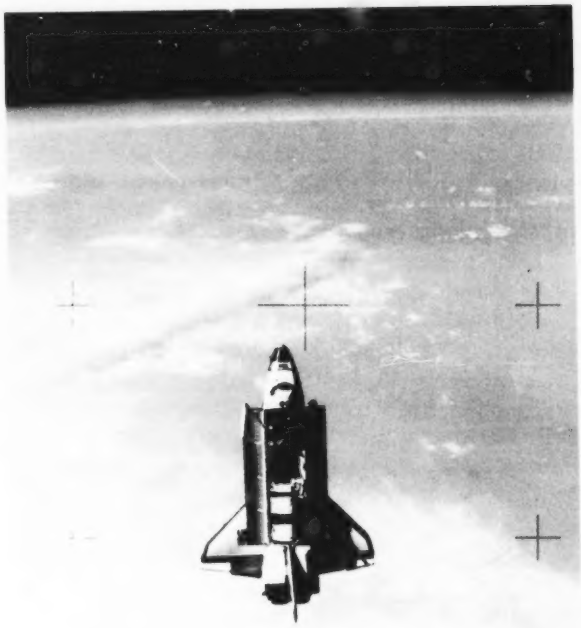
Shuttle missions for the Space Station Program will be dedicated missions, we do not expect there to be a requirement for a totally dedicated Shuttle orbiter, one reconfigured in a substantial way for use with the Space Station.



What are the major variables that will affect Space Station launch demands in the 1990's?

- **Configuration** - the design of the Space Station not yet been determined. Our current estimates are based upon the Reference Configuration portrayed in the Phase B Request for Proposal. Significant changes in Space Station design obviously could affect launch requirements.

- **STS Performance** - the estimates of possible Space Shuttle flight requirements for the Space Station incorporated conservative estimates of Shuttle Performance. Enhanced performance would increase the Shuttle's ability to carry Space Station cargos and could decrease slightly the number of flights required.

- **International** - although no agreements for developing Space Station elements have been negotiated or signed with our international partners, we included projected international flight requirements in our estimates. These requirements could vary depending on the nature and extent of international participation in the Space Station Program.

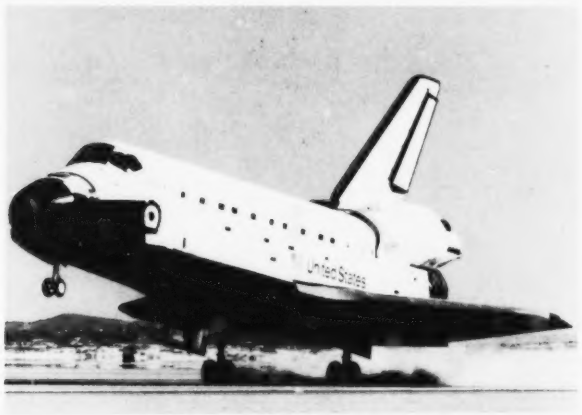
- **Commercial Users** - our planning assumptions for Space Station users include a substantial role for the commercial sector. There is a high degree of uncertainty in regard to the timing of such commercial participation in the Space Station Program. The uncertainty results in part from the lead time for such commercial ventures being less than the time between now and when Space Station becomes open for business. Our hope is that this uncertainty will diminish and our understanding of commercial requirements will increase as we fly commercial payloads aboard the Shuttle.

- **Servicing** - the servicing of Station elements and payloads is an important capability of the Space Station. As we gain operational experience the demand for this capability may grow significantly. Supplies and fuel will be needed at the Station, and increases in the number of flights required could occur.

- **Department of Defense** - the Department of Defense has not provided us with any requirements for the use of the Space Station. Consequently no allowance for DOD-related use is incorporated in these flight estimates.

- **Transition of Payloads** - some instruments and other payloads that were originally planned for single or repetitive flights on the Shuttle will be transitioned to the Space Station, when that is advantageous. Counting flights to support such payloads in the Space Station total is appropriate, but they should not be counted as additive to the originally planned experiment flights aboard Shuttle. More analysis needs to be done on this subject; for the present the point is simply that some payloads will shift from use aboard Shuttle to use aboard Space Station.

- **Evolutionary Growth** - as noted earlier, the Space Station will be designed to accommodate an increase in capability. The estimate of Shuttle flights we presented earlier did not include flights for developing a more capable Station. When an evolutionary Station is initiated in the 1990's, additional Shuttle flight requirements may emerge.



It seems clear that, regardless of the specific number of flights required during the 1990's to launch and sustain the Space Station, a substantial number of flights will be required. The Space Station represents a new capability in space. It is an outpost in orbit around the earth for the conduct of science, for the support of commercial enterprises, and for the development of new technologies. As a permanent facility, it represents an extension of mankind's ability to create, to produce, and to learn more of our world and its surroundings. Like any outpost, it will need to be supplied. As the Europeans sustained their New World outposts during the 17th Century and as we Americans transported men and materials ever westward to outposts beyond the Appalachians, then across the Missouri and eventually to the shores of the Pacific Ocean, we will supply our outpost in space. Over time many trips will be required and the costs will not be insignificant. But costs and transportation were part and parcel of America's transcontinental expansion and of Europe's New World colonies. The Space Station, our world's new outpost in space, will have similar requirements, but the benefits to mankind from taking this bold step, will, we believe, be substantial.

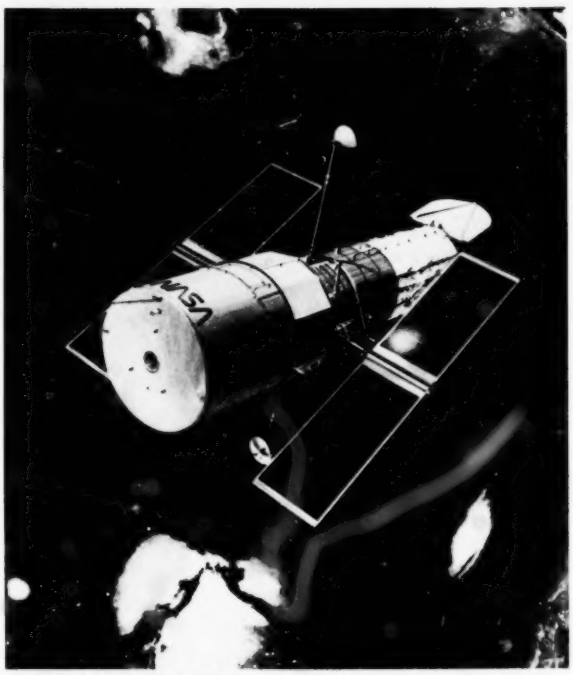
Science and Space Station

As noted earlier the elements of the Space Station that will be delivered by the Space Shuttle to low Earth orbit will consist of a manned base that we expect will initially accommodate a crew of six to eight people. The base will be composed of a number of modules which will provide laboratory and manufacturing facilities and living quarters for the crew, in addition to power generation and other ancillary facilities. Current planning also includes one or more unmanned free-flying space platforms which will operate away from, but in concert with, the Station base. These unmanned elements of the Space Station complex will be important for scientific experiments and observations requiring protection from the contamination and vibrations which are inevitably present in an inhabited spacecraft. They will also be important to the scientific community as they will be necessary for scientific instruments requiring extremely precise pointing. The platforms will be be serviced by the OMV. The OMV will initially be designed to retrieve and redeploy satellites from the Space Station and will eventually provide appropriate capability for *in situ* satellite inspection and repair. At least one platform is expected to be in polar orbit

A fundamental concept upon which the Space Station has been and will continue to be defined is that it will be designed, operated, and evolved in response to user interests. To assure that user needs and interests are satisfied as much as possible by the Space Station, NASA has, over the past three years, worked closely with prospective users to identify types of activities which would be of most interest to them for utilizing the various elements of the Space Station. These user requirements are reflected in the performance envelope of the Space Station which is in turn being used to guide the engineering design of Space Station systems. User activities encompass those identified by the commercial sector, the technology development community, and the science and applications community, both domestic and international.

In regard to utilization of the Space Station, we should point out that NASA has had a close working relationship with a number of outside groups. One of particular importance that we have already mentioned is the Task Force on Scientific Uses of the Space Station, chaired by Peter Banks of Stanford University. The Task Force is a derivative of the NASA Advisory Council's Space and Earth Science Advisory Committee. The responsibility of the Task Force is to advise NASA on the scientific utilization of the Space Station. This input is enabling us to identify and provide capabilities on the Space Station which will enhance those types of scientific activities which are unique to conduct on the Space Station. Composed of distinguished scientists from around the United States, the Task Force has been of great value to the program. Together with the Office of Space Science and Applications, the Office of Space Station has and will continue to consider and incorporate the recommendations of the Task Force to the highest degree possible.

Also, the program work package which is being managed by NASA's Goddard Space Center is almost totally concerned with the scientific applications of the Space Station. Goddard and its work package industry contractor teams are studying platform configurations, servicing, scientific payloads, and laboratories. We have also designated Dr. David Black as Chief Scientist in the Office of Space Station at NASA Headquarters. He is responsible for refining and interpreting science requirements, contributing to the establishment of policy to ensure the requirements are fulfilled, overseeing implementation of the policy, and coordinating with concerned Headquarters organizations as well as the external scientific community. Dr. Black works in close coordination with the Utilization and Requirements Division within the Office directed by Dr. William P. Raney.



THE SPACE TELESCOPE - orbiting far above the earth, free of the obscuring atmosphere, NASA's Space Telescope will enable astronomers to view distant stars and galaxies with clarity and precision. Launched by the Space Shuttle, the Space Telescope will be serviced on-orbit in the 1990's by the Space Station.

Let us now discuss a variety of scientific uses which have been identified for prime consideration as Space Station activities.

- Observations will be made of the Earth's solid surface, atmosphere, oceans, and ice both for research and operational purposes. These observations will primarily be conducted from the Space Station polar platform(s) in sun-synchronous orbit to permit observations of almost the entire planet. There will also be instrumentation on the manned base and co-orbiting platforms to permit more frequent observations of the tropical regions which are the source of much of the Earth's weather.

  In addition to NASA and our international partners, the National Oceanic and Atmospheric Administration (NOAA) is interested in making use of capabilities provided by polar platform(s). Indications of interest from commercial concerns exist also. A joint report to Congress which is being prepared by NASA and NOAA concerning long range remote sensing planning will discuss in detail the potential benefits of the polar platform concept.

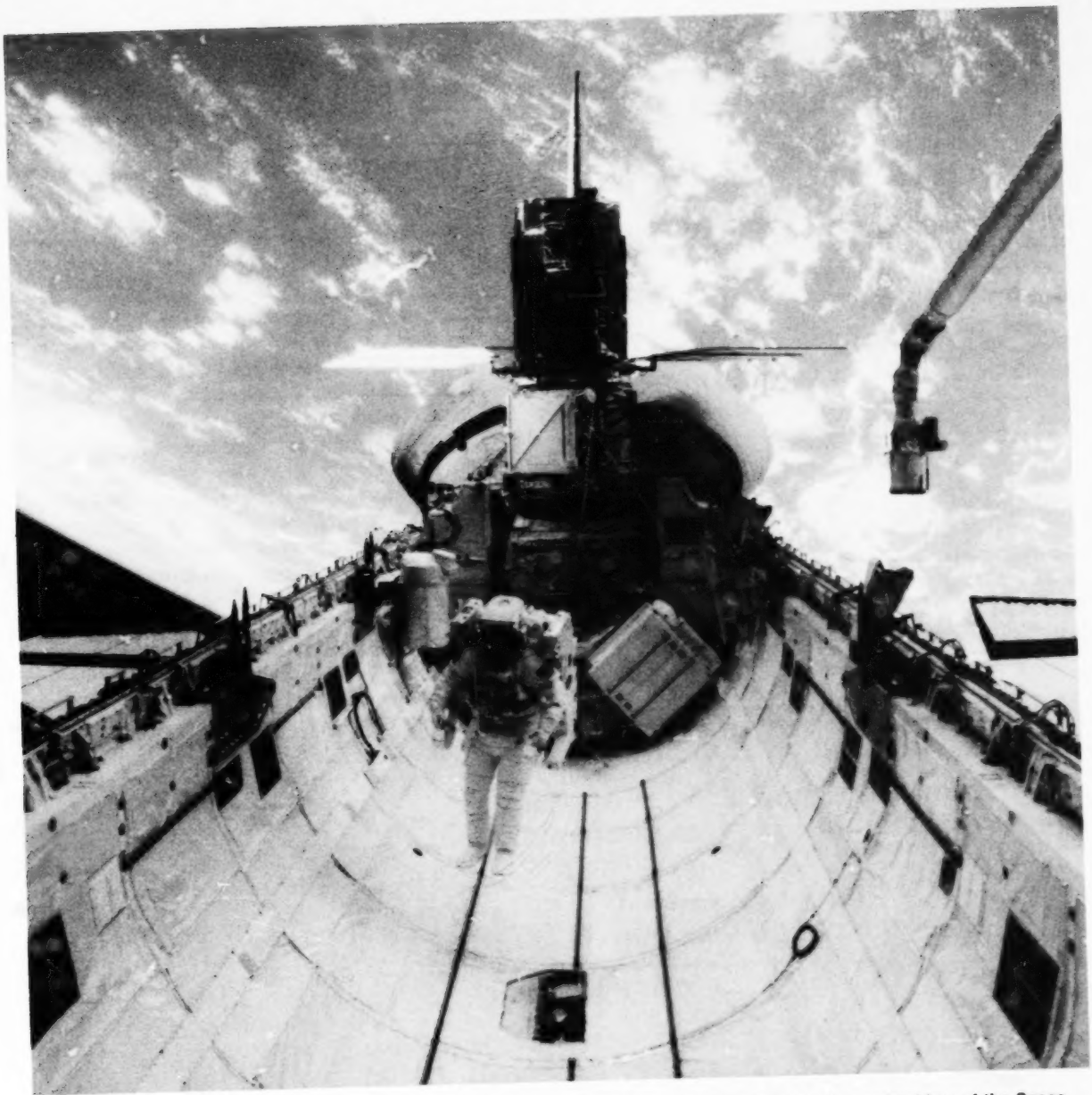
- Astronomical researchers appear interested in instrumentation attached to the manned base so that advantage may be taken of crew interaction, large resources which will be available on the Station, such as power and data acquisition systems, and long-term observational periods. However, most desire the capability of servicing provided by the manned element so as to extend the life of the spacecraft, to permit the exchange or modification of instrumentation, and to make any necessary repairs. Last year's Solar Maximum repair mission via the Shuttle, which restored the operation of a malfunctioning observatory, dramatically demonstrated the importance of an on-orbit servicing capability. The manned element will also play an important role in future astronomical missions as an assembly base for the construction of and deployment of large detector arrays, which will be key for improving detector resolution and sensitivity. Astronomical community workshops sponsored by the Office of Space Science and Applications the last two years have reflected great interest in these Space Station capabilities.

- The life sciences community is planning research programs in basic biology and physiology as well as the effect of long duration exposure to micro-gravity conditions on plants, animals, and humans. A cooperative international research program is anticipated by the science community in this area. The research will take place primarily on the manned base to permit the crew to serve both as experimentors and as subjects.

- Both the domestic and international user communities are enthusiastic about using the Space Station to conduct research into the processing and behavior of materials in micro-gravity. It is anticipated that such research will lead to pilot plant testing and, quite possibly, eventual full commercial production of materials in the Space Station's near zero gravity environment. Chemistry will be an important subject aboard the Station. Materials of interest include crystals, pharmaceuticals, and analogs of cometary, planetary and asteroidal materials. The laboratories of the manned element will be used for the research phase, permitting human interaction and control of the early experimental activity and allowing preliminary analysis of the results to be performed in space. This will enable much faster turnaround between successive experiments than has previously been possible. Full scale commercial production of materials may take place in the future using equipment attached to the manned element or on spacecraft which are serviced from the manned element. A large number of companies and the international participants have expressed a great deal of interest in this type of activity.

There is also great interest in using the Space Station for applications and technology research and development. Prospective usage includes the development and test of techniques for advanced communications, energy conversion, propulsion, controls and human factors including information systems, and structures, as well as improved Earth observations and astronomical instrumentation. Most of this activity is planned for the manned base to permit the crew to assist in the initial assembly of the instrumentation and then to act as researchers, modifying the instrumentation and the experimental protocols.

Other desirable user capabilities have potential for a future, evolutionary Space Station. In addition to an increase in capability to perform those types of activities desired in the early years, there is interest as well in staging missions to geosynchronous orbit or to



SOLAR MAX REPAIR — the Solar Maximum Mission Satellite ("Solar Max") is shown here in the payload bay of the Space Shuttle. After the satellite malfunctioned, Shuttle crews retrieved and repaired the spacecraft, which was then redeployed and began once again observing the sun. The Solar Max repair mission demonstrated again the value of a human presence in space.

planetary trajectories which require on-orbit assembly in order to obtain greater mission mass than is possible with the Space Shuttle alone. Interest has also been expressed in providing for the capability to service spacecraft in geosynchronous orbit in order to extend their lifetime or to permit the addition of new instrumentation to the spacecraft to alter, or increase, its capability.

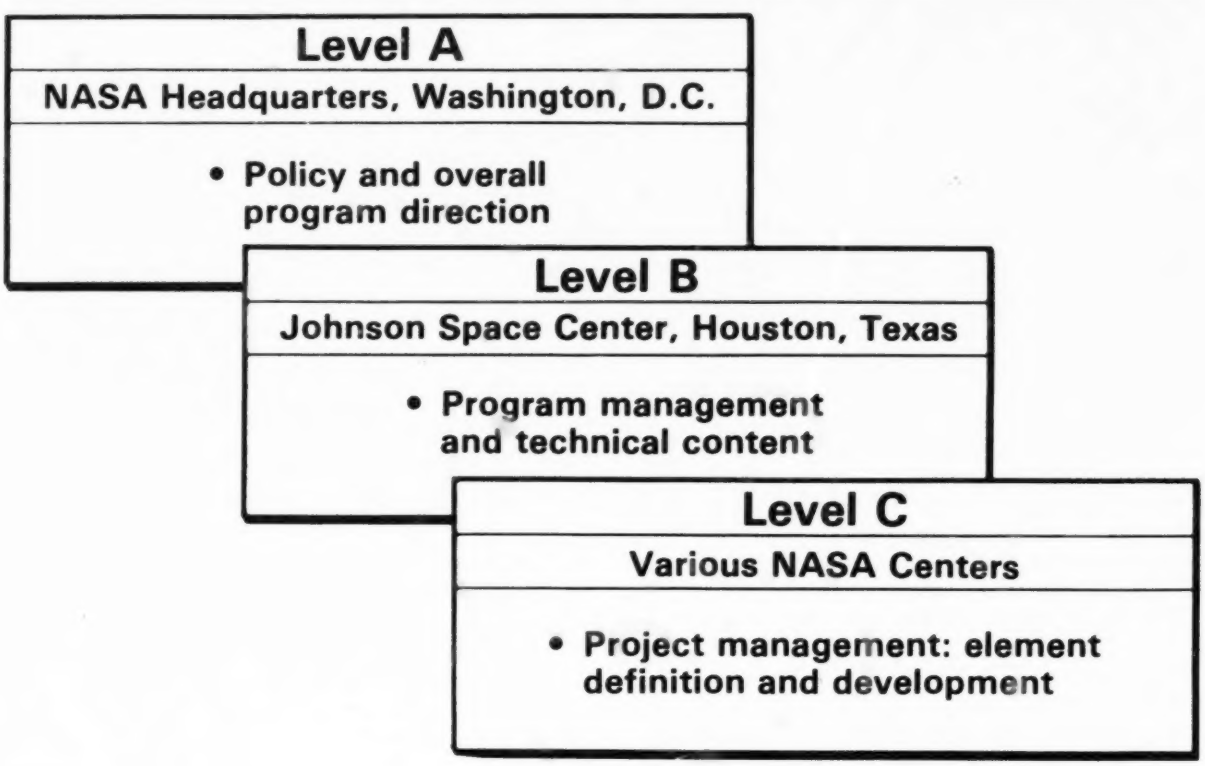
These and other user interests and requirements continue to be defined by the Space Station Program in conjunction with the user community and outside advisory groups. The information will guide the Space Station design so that the value of the Station to science, commerce and technology is maximized. At the same time, however, let us issue a note of caution. NASA, its international partners, and the user

community must be realistic about the degree to which all of the desired user activity can be brought to fruition in the 1990's. The Space Station will be a remarkable and versatile system, but its initial orbiting capability is not likely to be able to initially accommodate or provide the entire spectrum of capabilities for all who wish to utilize it.

NASA expects that the Space Station will be capable of satisfying currently anticipated *types* of user activity. The scientific community, as well as other user groups, is becoming increasingly aware of the capabilities which the Station and its platforms will provide. As a result, fresh and imaginative ideas continue to appear at a growing rate for the use of this new and truly valuable resource. The Space Station will be used by the scientific community in ways which we have not yet even conceived.

To implement the many activities of the Space Station Program, we have established a management structure which features a three-tiered allocation of responsibility. Level A at NASA Headquarters in Washington is responsible for the policy and the overall direction of the program. Level B, located at the Johnson Space Center in Houston, is responsible for program management and the technical content of the program. Level B is also responsible for integrating the work of the Level C centers which are responsible for discrete project elements.

SPACE STATION PROGRAM MANAGEMENT APPROACH


Level A
NASA Headquarters, Washington, D.C.
• Policy and overall program direction
Level B
Johnson Space Center, Houston, Texas
• Program management and technical content
Level C
Various NASA Centers
• Project management: element definition and development

Commerce in Space

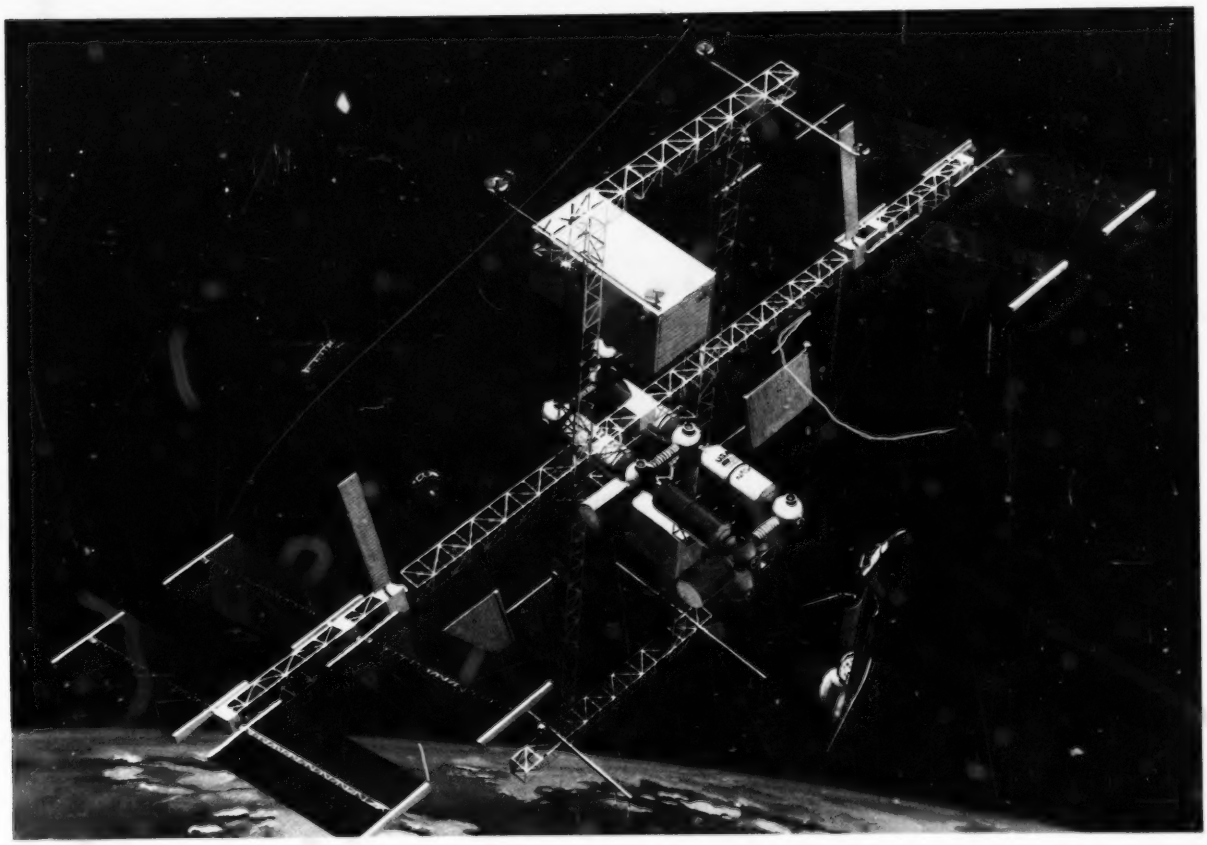
We in the United States believe that the private sector role in space will increase substantially in the future. A key dimension of United States national space policy is to foster such participation. The policy states in part:

> *"The United States Government will provide a climate conducive to expanded private sector investment and involvement in space activities, with due regard to public safety and national security."*

Space, of course, is already commercialized. In the United States and in Europe, the communications industry is now is large part space-based. In Italy, for example, industry has benefited from an early recognition that "comsats" are a profitable undertaking. Expendable launch vehicles and upper stages are presently subjects of commercial investment. Efforts to make remote sensing from satellites profitable are underway in France and the U.S. Materials processing is also a candidate for space-based commercial activities. Research in Canada, Japan, West Germany, and the United States point to a potentially large market for materials processed in space.

In response to a recent Presidential directive intended to accelerate participation of the U.S. private sector in space, NASA has reexamined its own role in fostering the commercial utilization of space. New policies are in place and a new Office of Commercial Programs has been established in NASA to provide focus and direction to the agency's activities. NASA realizes that the initial frontend risks of space ventures must be reduced. It understands that respect for intellectual property and proprietary data are essential requirements for any commercial endeavor in space. And it knows that for space to realize its true commercial potential, practical-minded businessmen must be convinced that their company can profit by going into space.

In planning the Space Station, NASA is focusing upon making sure the Station is conducive to use by customers, one category of which is expected to be commercial enterprises. The benefits to commercial customers of an operational Space Station in orbit and "open for business" are multifold. The Station itself,



as a permanent facility, offers the kind of program stability and continuity private investors seek. Another benefit is the capability represented by the pressurized laboratory module(s) and platforms that will serve both science and commerce. Another is the repair and assembly capability the Space Station will have. Still another, and perhaps a critical one, is the presence of man, permanently and without the constraints of time on-orbit associated with present spaceflight activities.

NASA is also focusing upon commercial enterprises that could participate in the development and operations of the Space Station and its platforms. A set of guidelines has been proposed that provide a policy framework for entrepreneurs who wish to join NASA in the Space Station Program. These guidelines have been circulated for comment and will be adopted once the comments are analyzed.

Further into the future as new technologies mature and as experience is gained with the Space Station's repair and assembly capabilities, commercial prospects look even brighter. Indeed it is not difficult to see a dedicated module, or even a separate Space Station, owned by private business, devoted exclusively to commercial operations.

* * *

NASA programs have traditionally served to stimulate the imaginations of our young people, to stimulate them to become interested in new scientific endeavors and in the world of constantly emerging new technologies. The capabilities of this unique, new space facility — the Space Station — and the visions which it will provide to the future generations of Americans will help continue this national interest in science and engineering, thereby ensuring this nation's leadership in technology and the world of knowledge.

Philip E. Culbertson *is the NASA Associate Administrator for Space Station*

Robert F. Freitag *is the Director, Policy and Plans Office, Office of Space Station at NASA Headquarters*

SPACE STATION PROGRAM PLAN

- **Establishes a strong role for NASA in program management**
- **Provides genuine competition among U.S. industry**
- **Supportive of meaningful international participation**
- **Gives strong voice to Space Station user communities**
- **Allows for growth and increased capabilities**
- **Establishes a substantial effort in technology development**
- **Provides for credible cost, schedule and technical projections, through extensive definition phase**
- **Will enable NASA to meet President Reagan's "within a decade" directive**

"The U.S. is committed to develop a permanently manned Space Station. NASA and industry are now hard at work on a wide-ranging set of activities that could lead to an operational system in the 1992-94 timeframe. President Reagan has issued the directive. Congress has been supportive, mindful of its obligation to reduce the deficit, yet conscious of its responsibility toward their nation's future.

The stakes are enormous. The issue is leadership. We must continue to lead in space science and its applications, in space technology, in space-based commercial operations, and in manned space flight. The Space Station Program will ensure that we do. With the Space Shuttle becoming truly operational, the Space Station is indeed the next logical step for our nation to take."

John D. Hodge
Deputy Associate Administrator
Office of Space Station